METEOROLOGICAL POTENTIAL OF THE VIKING-2 SEISMOMETER DATASET

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Introduction The Viking landers each carried a sophisticated seismometer [1,2], and that of Viking 2 operated for over 500 sols [3]. Although the data are usually dismissed as of limited value due to the susceptibility of the lander-mounted instrument to wind noise, they were able to exclude high global seismicity on Mars, with only one candidate local seismic event being identified. The data may merit closer attention from modern geophysical data analysis methods, and are in fact of interest in atmospheric science since the instrument was sampled better than the meteorology package. However, the Viking mission predates the emergence of standard formats for digital seismic data, and pre-dates the PDS. The deep public archive at NSSDC is in an unfriendly format, driven by the limited data handling capabilities of the mid-1970s. Here we report an effort to make the Viking data more readily available to the community, and an initial investigation into the relationship between meteorological conditions and the seismic data. Such a re-examination is all the more pertinent given the forthcoming InSight mission : even a ground-emplaced and wind-shielded seismometer will sense wind energy coupled into the ground, and possible surface deformation in response to pressure fields [4].

Viking Seismometer: The Viking landers had the principal goal of detecting life on the Martian surface, and geophysical and meteorological instrumentation suffered a number of compromises in accommodation [1]. Most notably, the seismometer was mounted on the lander deck. Although for seismic periods of interest the coupling of the instrument with the ground was adequate (contrary to what is often asserted), this arrangement did cause the noise floor of the instrument to be often rather high due to wind-induced motion of the lander body on its compliant legs. For extended periods (especially at night) when wind was low, the instrument was useful.

The instrument was a 3-axis velocity sensing instrument (essentially similar to a magnet-coil geophone with an appropriate spring arrangement to give a resonant frequency of about 3 Hz). The 2.2kg, 3.5W instrument included variable gains and filters and (for the time) elaborate data handling.

Seismometer Data : The instrument had a sensitivity corresponding to about 2nm of displacement at 3Hz, and 10nm at 1Hz. The instrument recorded in 3 modes, Normal, Event and High Data Rate, with rates of ~6, 145, and 1800 kbits/hr respectively. The Normal mode simply records the background amplitude 4.04 times per minute. The High Data Rate mode samples each axis directly at 20.2 Hz, but its data rate precluded extensive operation. Much of the data are in Event mode, which records the envelope in each axis at 1.01Hz, as well as the number of zero crossings (thus a measure of frequency) in the same interval.

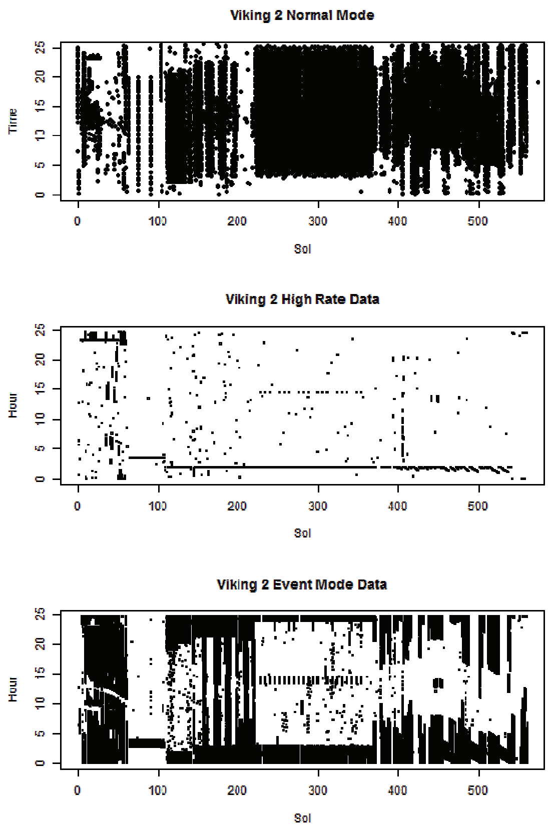

Figure 1. Extent (Sol vs time of day) of Viking seismometer data acquisition in Normal, High rate and Event modes. Because of bandwidth limitations, relatively few High rate measurement sessions were performed. Event mode data has a rather better coverage, but is concentrated in the late night and early morning when the wind noise was minimized.

Measurement packets are typically 53 samples long in Event mode, and 83 samples long in Normal or High Rate mode (to put these in a familiar modern context, it may be remarked that these record lengths are comparable with text messages or tweets). The data comprise about ~49,000 High rate records and ~22,000 Normal mode, with the majority of the dataset (273,000 records) in Event mode. In total [3] the Viking 2 seismic record corresponded to about 2100 hours of measurement (89 days) up until sol ~560, when a lander mass memory unit required for seismometer data handling failed. The lander itself continued to function for much longer (~1050 sols). Because the wind background was low at night, seismometer operation was concentrated at that time (figure 1).

Data Products : Most of the data has been recovered into usable ASCII files, with only occasional manual surgery required to fix transcription errors. We have begun working with the PDS Geosciences node deliver to the PDS these files of 'raw' data with documentation, and prepare higher-level data products that we consider will be useful, at least for atmospheric science (for example, a catalog of the records that can be used to give a long-term overview of amplitudes like that in [5]) and concatenated records of selected segments of data at its native resolution where it is of good quality. A catalog of known disturbance events will also be archived.

Initial Examination and Interpretation : It was recognized at once that as expected, wind was a significant contributor to the seismometer signal, and a preliminary correlation [2] showed that the amplitude of the seismometer output (displacement) was proportional to the square of the wind speed. Further analysis [5] showed that the wind and seismic records were highly coherent, and that several known periodicities in Mars atmospheric behavior could be identified in the seismic data.

Here we show (figure 2) that on diurnal timescales the wind and seismic noise level are somewhat coherent, but we can detect the enhanced stability of the atmosphere in night. Despite a mean wind speed similar to earlier in the day, the seismic noise falls significantly after about 5pm local time. This is presumably due to a stable layer of cold air forming by radiative cooling.

Conclusion : Even though the Viking seismometer is an imperfect anemometer and has challenging data limitations, the size of the record and its rapid sampling means it can contribute significantly to Mars meteorology, particularly with regard to turbulent winds.

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References: [1] Anderson, D. L. et al., The Viking Seismic Experiment, Science, 194, 1318-1321, 1976 [2] Anderson, D. L. et al., Seismology on Mars, Journal of Geophysical Research, 82, 4524-4546, 1977 [3] Lazarewicz, A. R. et al., The Viking Seismometry Final Report, NASA Contractor Report 3408, 1981 [4] Lorenz, R. D., Planetary Seismology - Expectations for Lander and Wind Noise with Application to Venus, Planetary and Space Science, 62, 86–96, 2012 [5] Nakamura, Y. and D. L. Anderson, Martian Wind Activity Detected by a Seismometer at Viking Lander 2 Site, Geophysical Research Letters, 6, 499-502, 1979

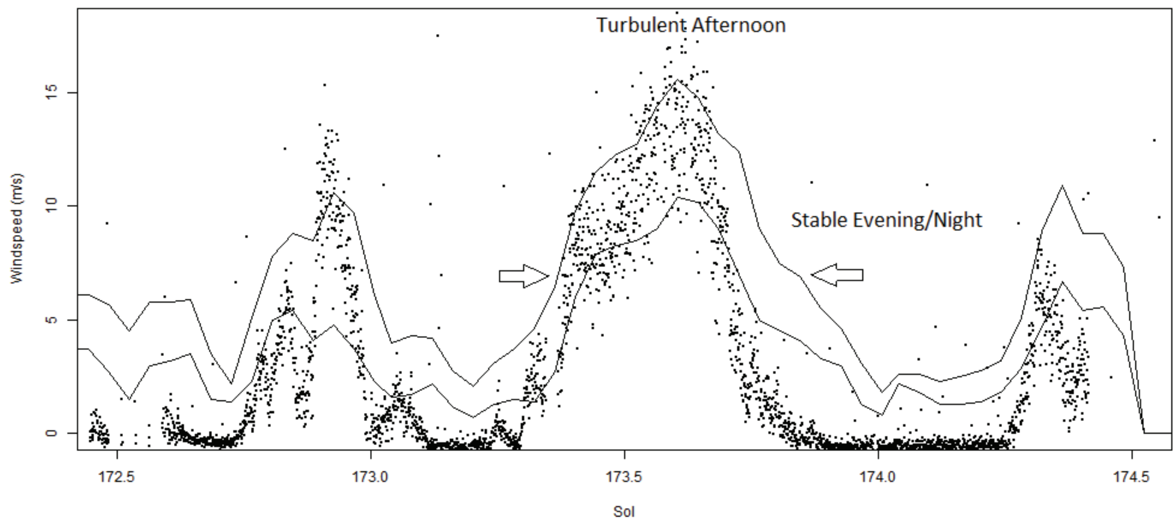

Figure 2. Short-term wind variations revealed in seismic data. The current PDS archive has only the hourly averaged winds data (dataset VL1/VL2-M-MET-4-BINNED-P-T-V-V1.0). The mean plus/minus one standard deviation of the archived hourly windspeed is plotted for Sol 172.5-174.5 as lines. The datapoints - here from a particularly well-populated sequence of Event-mode records - are an arbitrarily-scaled square root of the X-axis (vertical) amplitude of the seismometer output (nm/s). In general the two datasets track well, showing a clear diurnal variation. It is noticeable that the night-time winds are apparently rather smooth. Not only does the standard deviation (in the PDS file, computed from the original wind measurements) decrease (especially at ~174.1), but the seismic noise in the evening and early morning (e.g. around 173.9) is lower compared with that seen at the same windspeed earlier in the day, at 173.4 (see open arrows). This is presumably due to the stability of the atmosphere due to radiative cooling of the surface at night (although wind direction may also be a factor) and shows that the seismic noise level is diagnostic of meteorological conditions but is not purely a function of the average windspeed.